EFFECT OF SHRUBS ON PLANTED TREE SEEDLINGS IN CENTRAL IDAHO

FINAL REPORT FOR RESEARCH AGREEMENT
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"Effect of Shrubs on Planted Tree Seedlings in Central Idaho"
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Introduction

Ecological interactions with a negative component (predation and competition) have received more attention in the last decades than have beneficial ones (Begon et al. 1986). In a discussion of beneficial interactions, Hunter & Aarssen (1988) coined the word "beneficence" to include mutual and commensal interactions.

Seedling establishment, requiring both survival and growth, usually occurs in the context of neighbors. In the coniferous forests of the Pacific Northwest, tree regeneration after timber harvest is often not as fast or as complete as desired. Seedlings often must interact with a variety of neighbors including grass, herbaceous, and woody species. Stewart et al. (1984) and Tappeiner et al. (1992) provide overviews that indicate that the majority of the interactions examined are competitive, and detrimental to the conifer seedlings. Recent examples (Harrington & Tappeiner 1991; Wagner & Radosevich 1991a,b; Knowe et al. 1992; Conard & Sparks 1993; Tesch et al. 1993; McDonald et al. 1994) confirm this generalization.

There is evidence however, that in some cases, proximity to shrubs can increase seedling survival (Wahlenberg 1930; Minore 1971; Tappeiner & Helms 1971; noted by Gratkowski & Lauterbach 1974; Coffman 1975; Youngberg et al. 1979; Helgerson 1990a; see also Helgerson 1990b) or at least not reduce survival (Tesch & Hobbs 1989; Tesch et al. 1993). Gratkowski (1961) notes that brush sometimes seems to favor forest regeneration. Mechanisms for this "nurse plant-type" interaction include shade and the resulting lowered soil surface temperatures (Youngberg 1966; Tappeiner & Helms 1971; Minore 1986a, Jones 1995), increased soil moisture (Youngberg 1966; Minore 1986a; Lopushinsky & Klock 1990), and increased air humidity (Tappeiner & Helms 1971). Shade from sources other than live shrubs also has been found to increase survival (Shearer 1981; Conard &

Radosevich 1982; Hobbs 1982; Minore 1986b; Childs & Flint 1987; Hungerford & Babbitt 1987; Conard & Sparks 1993).

With regards to conifer seedling growth, the vast majority of reports support competitive inhibition by neighbors (e.g., Stewart et al. 1984; White & Newton 1989; Wagner & Radosevich 1991a,b; Shainsky & Radosevich 1992). However, Knowe et al. (1992) reported increased early growth, and Klinka et al. (1989) found no effect.

Little conifer regeneration / shrub research has been done in Idaho. McConkie & Mowat (1936) obtained preliminary data on the factors affecting ponderosa pine and Douglas-fir seedling establishment and suggested that survivorship was promoted in the presence of shrubs. Hall & Curtis (1970) and Hall (1971) examined the effects of site preparation technique on the survival and growth of ponderosa pine. The various site preparations affected the degree of shrub competition. Shrub removal resulted in greater survival and height growth of the seedlings. Kittams & Ryker (1975) examined Douglas-fir survival under various site preparations and in a variety of habitat types; removal of other vegetation increased conifer survival and height growth. Geier-Hayes (1987, 1994) examined the distribution of seedlings in a variety of habitat types in south-central Idaho, and found that shrub cover may be associated with better seedling establishment; Jones (1995) found that naturally regenerated Douglas-fir seedlings were associated with shade and shrubs.

The purpose of this project is to examine the effects of shrubs on the artificial regeneration of Douglas-fir seedlings in south-central Idaho. My primary hypothesis is that under our local hot, dry summer conditions, some shrub species may provide beneficial conditions for young seedlings. This would be expressed as a positive association between shrub presence and seedling survival and/or growth.

Study Sites

Eight study sites were established in 1989 and 1990 in the following habitat types within the Douglas-fir series (Steele et al. 1981):

Pseudotsuga menziesii / Carex geyeri (Psme/cage)

" / Calamagrostis rubescens (Psme/caru)

" / Spiraea betulifolia (Psme/spbe)

" / Physocarpus malvaceus (Psme/phma)

" / Symphoricarpos oreophilus (Psme/syor) and

/ Acer glabrum (Psme/acgl) (within one site)

These habitat types occur over a range of moisture conditions. The study sites were either in the Boise National Forest or on adjoining Boise Cascade land (Table 1).

Site selection was restricted to approximately three-year-old clearcuts. After clearcutting, replanting is not always immediate; some shrub individuals get a one to two-year head start over planted conifer seedlings. Shrubs continue to regenerate; the conifers have, in turn, an advantage over the later shrubs. Using 3-year-old clearcuts simulated actual logging situations, with shrubs regenerating both before and after planting.

Both scarified and burned clearcuts were utilized so as to include the major shrub species (e.g. Ribes individuals regenerate more readily in scarified areas, whereas Ceanothus is more likely to become established in burned areas). Because of the long-term nature of this study and yearly fire danger, several smaller, more geographically isolated study areas were chosen. Three study areas were placed on recent, comparatively safe burns.

Two-year-old bare root Douglas-fir seedlings were obtained from either the Forest Service or Boise Cascade Corporation. They had been grown either at the Lucky Peak or Coeur d'Alene Nurseries,

and were of the appropriate origin (elevation and geographic region). Planting was done according to Forest Service specifications (Tixier 1982). The planting arrangement was an 8' x 8' grid. Site preparation involved hand scalps (18" x 18", using a McLeod hoe), and planting was by auger. The one exception that was made to Forest Service procedure was that shrubs were not removed from the scalped area; their presence was the essence of this study.

Methods

Field Data Collection

Seedling growth was quantified in the field using the following parameters -- 1) height to the tip of the most distal bud, 2) stem diameter at 10 cm above soil level, and 3) two perpendicular crown diameters. Measurements were taken at the time of planting and near the end of each growing season. Seedling survival was also noted yearly.

Seedling canopy volume growth was chosen as the measure of regeneration success (Howard & Newton 1984; Lanini & Radosevich 1986; Shainsky & Radosevich 1986). Seedling canopy volume was defined as seedling height x area. The growth in seedling canopy volume was calculated in two ways, assuming either linear or exponential growth. Proportional change in seedling volume, assuming linear growth, was defined as:

$$\frac{\text{volume yr}_t - \text{volume yr}_0}{\text{volume yr}_0}$$

Seedling relative growth rate (RGR), assuming exponential growth, was defined as (Hutchings 1986):

$$\frac{\log_e \text{volume yr}_t - \log_e \text{volume yr}_0}{t}$$

In both formulas, year_t = year when measurements were taken and yr_0 = year of planting. In a few

analyses, volume yr $_{t-1}$ was substituted for volume yr $_0$.

Stem diameter can be a better indicator of competition than stem height (or canopy volume) (Wagner and Radosevich 1991a; McDonald et al. 1994). Therefore, proportional change in stem diameter was employed as an additional measure of seedling growth. Height (cm)/diameter (cm) ratios (H/D) were calculated to examine the effect of shading (Hughes et al. 1990).

This study used the neighborhood approach (Coates 1987; Wagner and Radosevich 1991a) to examine the effect of neighboring plants. Shrub presence (within a 1.5 m radius neighborhood of each seedling, see Fig. 1) was quantified by species (Table 2), each growing season, using four parameters--height, area, distance from seedling, and position relative to compass direction north (azimuth). In general, parameters were recorded for each shrub in each seedling neighborhood. Exceptions included 1) clonal species (e.g., Spiraea betulifolia), in which shoots of similar size and position were grouped, and 2) species with shoots of highly variable height (e.g., Prunus virginiana), for which an individual plant was sometimes quantified in more than one part so that area and height were accurately recorded. A few species (e.g., Berberis and Rosa) were omitted because of their rarity and small stature.

Variables (collectively called Shrub Importance Values, or SIV's) describing shrub importance (see Wagner and Radosevich 1991a; Coates 1987) were calculated from the annual shrub measurements. Shrubs may interfere with seedlings through competition, or benefit them, through shading for example. Shrub volume (representing biomass, Murray & Jacobson 1982) may better reflect competitive ability, whereas shrub height may reflect shading ability. Seven SIV's were developed, based on shrub height or volume, including different subsets of the shrubs and weighting the shrubs by either distance or distance^2 (Weiner 1982) from seedling. SIV's A - G are defined as follows:

A = volume/distance^2 from seedling;

B = height/distance^2;

C = height/distance^2, limited to shrubs $\pm 100°$ from south;

D = height/distance^2, limited to shrubs tall and close enough to intercept the sun's arc on July 23

E = height/distance, limited to shrubs tall and close enough to intercept the sun's arc on July 23;

F = volume/distance^2, limited to shrubs within 1 m;

G = height/distance^2, limited to shrubs within 1 m.

Two series of SIV's were calculated for use in different analyses: 1) for each shrub species around a seedling, and 2) for all shrub species combined around a seedling.

Though the main purpose of this project was to examine the effect of shrubs on seedlings, it was decided that an examination of other possible factors would result in stronger results and more predictive power. Therefore, several other aspects of seedling neighborhoods were also quantified. Each growing season, shrub cover was estimated for each quarter neighborhood (NE, SE, SW, and NW), and the four values averaged. Grass/sedge cover and herbaceous plant cover (only 1992-1995) were similarly quantified. Slope and site preparation (no preparation, burned, scarified, or warmed) were recorded for each seedling. The degrees of shade received by each seedling as the sun made its arc on July 22 (midpoint of the hottest period of the summer) was determined using an instrument designed by Jones (1995). This included shade produced by dead and alive trees as well as shrubs, and by the horizon (flat east and west horizons were 0° and 180°, respectively). Degrees of shade were summed for each seedling to produce the following variables: PMSHADE (shade from 9 am (45°) - 6 pm (180°), NOONSHADE (12 noon (90°) - 2 pm (120°)), and MIDDAYSHADE (12 noon (90°) - 4 pm (150°)). These three variables showed little difference in explanatory power; the latter was more biologically relevant and was used in final analyses.

Statistical Analyses

Seedling Survival Analyses

All statistical analyses were done using SAS (1990). Logistic regression was used to assess the effect of independent variables on seedling survival. This procedure allows the examination of several independent variables and a dependent variable with only two possible values (survival or non-survival in this case). It indicates the increase in odds of survival caused by an incremental change in an independent variable. Because mortality was largely confined to the first years after planting, these analyses examined survival to year 4.

Initially, logistic regression was used to examine the effect of all shrub species combined on the odds of seedling survival. Analyses were done on survival to year 4, and repeated for SIV's A-D. One set of analyses was done on all sites together, excluding shade and herbaceous plant independent variables (not available at all sites), and restricting seedlings to those that lived through one growing season. A second set of analyses included only sites with all independent variables measured (all except Lone Pine and Nixon Rock), restricting seedlings to those that lived at least 12 months.

These results led to logistic regressions examining the effect of individual shrub species on the odds of survival. Analyses were done on survival to year 4, and repeated for SIV's A-C ; independent variables included shrub importance values, slope, grass cover, and bush cover (1993 data). Only seedlings that lived at least through the first growing season were included; deaths before this were likely due to planting errors and not associated with the independent variables (Ruth 1957).

Site preparation was not included in multivariate survival analyses; therefore, the possible association between site preparation and survival was examined in chi-squared analyses. Site preparation categories included no preparation, burned, scarified, warmed, scarified and warmed-or-burned. Five-year sites (1989-1993) combined and four year sites (1990-1993) combined were analyzed.

Seedling Growth Analyses

SIV's and other neighborhood parameters were used as independent variables in stepwise linear regressions. Analyses were done on sites individually; in most cases the dependent variable was seedling canopy volume growth. Analyses were as follows: 1) Separate analyses involving 1993, 1994, and 1995 data, using proportional change in seedling volume since planting as the dependent variable; 2) analyses using 1995 data and RGR since planting as the dependent variable; 3) separate analyses using 1993, 1994, and 1995 data with proportional change in seedling volume over one year as the dependent variable; 4) analyses using 1995 data and proportional change in stem diameter since planting as the dependent variable. Since stem diameter is one-dimensional, the linear model (proportional change in variable) was considered more appropriate for the last analyses than the exponential one.

All neighborhood variables except site preparation and aspect were included in the multivariate analyses described above. The influence of site preparation on seedling growth was examined with ANOVA. Because aspect is a circular variable, its influence on seedling growth was examined with a circular/linear analysis (Batschelet 1981). Because shade is of particular interest in this study, simple linear regressions were done of seedling growth on the shade variable MIDDAYSHADE.

The influence of shrubs on H/D ratios was examined with regression (summed SIV's for all shrub species together were used as the independent variable). Sites were examined separately.

Results

Seedling Survival

Seedling survival is shown in Figure 2. Mortality was highest in the first two years after planting.

The presence of shrub species combined is associated with increased odds of survival (Table 3)

when shrub importance incorporates height (SIV's B-D). Shrubs that have the potential to shade (SIV's C and D) have a strong effect, relative to other terms in the model.

Logistic regression indicated that individual shrub species can increase, decrease, or have no significant effect on the odds of seedling survival (Table 4). Ceve had the most consistent positive effect. If only the shrubs at ± 100° from south are included, more shrub species significantly increase the odds of survival. In that the relationship strengthens when limited to southerly shrubs, shade may be the mechanism of "beneficence." It does not appear to be specific to species.

For 5-year sites combined, a significant association was found between site preparation and survival ($P < 0.001$). The "burned" preparation was found more than expected among the survivors; "no prep" and "warmed" categories were found more than expected among the non-survivors. For 4-year sites combined, a significant association was found between site preparation and survival ($P < 0.001$). The "burned" preparation was found more than expected among the survivors; "no prep" and "scarified" were found more than expected among the non-survivors. The results indicate that higher survival is associated with burned planting locations.

Seedling Growth

Tables 5 (a-c) present results from stepwise linear regressions on the effect of neighborhood variables on proportional change in seedling volume since planting. Analyses were done on sites individually (except Nixon Rock sites 1b and 1c which were in close proximity, similar in vegetation, and had small sample size). Independent variables are only listed if significantly ($P < 0.05$) positive or negative. Note that most variables are not listed; they were neutral. Of those that are both significant and positive, the majority involve shrubs. There are few negative interactions involving shrubs. Grass/sedge cover was generally neutral, and sometimes negative.

The effect of neighborhood variables on seedling RGR since planting was examined using 1995

data (Table 6). Results are similar to those found with proportional change in seedling volume as the dependent variable (Table 5c). The Elk Creek site showed higher r^2 values in the RGR analyses, suggesting that exponential growth is now occurring there. Conversely, the Warm Springs, Alder Creek Summit, and Thompson Gulch sites better fit the assumption of linear growth.

The effect of neighborhood variables on proportional change in seedling volume over single year periods is shown in Table 7. As in the analyses on growth since planting, the majority of significant positive effects involve shrubs. There is no obvious pattern of increasing or decreasing influence with time, nor are particular neighborhood variables consistent in their effect.

The effects of neighborhood variables on proportional change in seedling stem diameter (1995 data) are summarized in Table 8, and are similar to those presented in Table 5c.

Site preparation had a significant effect on proportional change in seedling volume (6-year sites combined, ANOVA, $P < 0.002$). However, Scheffe's Test produced no significantly different site preparation groupings. At King Gulch East, the "burned" preparation was associated with better growth than the "scarified and warmed or burned" preparation ($P < 0.006$). At Nixon Rock site 1b, site preparation had a significant effect ($P = 0.0001$, $r^2 = 0.90$). However, sample sizes there are so small that I question the validity of the results. The results were similar using seedling RGR as the dependent variable. In summary, site preparation did not significantly affect seedling volume change at most study sites.

The possible influence of aspect on proportional change in seedling volume was examined with a circular/linear analysis. Analyses were done for 1) 6-year sites combined, 2) 5-year sites combined, and 3) all sites individually. A significant ($P \leq 0.05$ in each case) relationship was found for all 6-year sites combined, all 5-year sites combined and the King Gulch East site; however, r values were between 0.01-0.065, indicating very little influence of aspect on seedling volume change.

Regression analyses were done for sites individually with middayshade as the independent

variable. At Elk Creek there was a nearly significant negative relationship between middayshade and proportional change in seedling volume ($\underline{P} = 0.08$, $r^2 = 0.02$). At Warm Springs, Alder Creek Summit, King Gulch West, Thompson Gulch, and King Gulch East, the relationship was positive, but only significantly at King Gulch East ($\underline{P} < 0.05$, $\underline{r}^2 = 0.02$) and Thompson Gulch ($\underline{P} = 0.06$, $\underline{r}^2 = 0.04$). The shade variable thus explains little of the variability in seedling growth. However, the influence of increasing shade is generally positive, up to a point. Elk Creek is a very shrubby site, where an increasing amount of shade is detrimental to seedling growth.

H/D ratios ($\overline{x}$ ± S.D.) of living seedlings were as follows: at planting - 50.6 ± 12.0; 4 years - 58.7 ± 16.8; 5 years = 55.9 ± 15.2; 6 years - 53.5 ± 14.7; 7 years - 51.5 ± 13.4. Seedlings (N = 65) that died between years 4-6 (or 7) had $\overline{x}$ ± S.D of 61.3 ± 23.2 in their last year of life. Of the 808 seedlings alive in 1995, 89 had values over 70 (considered a cut-off for possible successful regeneration by Hughes et al., 1990). Summed SIV's accounted for 1-30% of the variability in H/D ratio at the different sites (only King Gulch West had a value greater than 10%). Considering only seedlings with H/D ratios over 70, only at King Gulch West did they tend to have the higher summed SIV's.

Discussion

The results presented here suggest that neighboring shrubs are sometimes associated with increased Douglas-fir seedling survival and growth. It would be expected from the literature that neighboring shrubs would have a negative association with seedling growth (see Introduction). Ecologists have emphasized for many years the role of competition in ecological communities and, in some, it clearly is an organizing influence (Begon et al. 1986). In this study, the majority of shrub species were found to have no significant effect on seedling growth. Among the significant associations found between seedling growth and shrubs, the majority were positive and a few were negative. In a

study of interactions of annuals, McConnaughay & Bazzaz (1990) also found many neutral interactions, as well as some positive and negative ones. Many examples of plant/plant beneficence (commensalism and mutualism) are known. Such interactions can occur simultaneously with competition (Hunter & Aarssen 1988). It is quite possible in the current study that beneficial and detrimental interactions are occurring together (e.g. a shrub species reduces light, but provides more favorable soil moisture conditions). What is of interest, considering the literature, is both that negative competitive interactions do not dominate, and that beneficial ones do occur.

This study examined the influence of neighboring shrubs, both overall and individual species, on the odds of seedling survival. Shrub species combined, when quantified by the variable height, were associated with increased odds of seedling survival. The relationship strengthened when analyses were limited to those individuals with the potential to shade. Individual shrub species were found to increase, decrease, or have no significant effect on the odds of seedling survival. More shrub species were found to increase the odds when only southerly shrubs were included, again suggesting shade as the mechanism of interaction.

In studies such as this, there is no consensus as to what variable should be chosen to quantify conifer growth. Stem volume (e.g. Tesch et al. 1993; Shainsky & Radosevich 1992) and canopy volume (Lanini & Radosevich 1986; Shainsky & Radosevich 1986) are two possibilities. There is concern, however, that variables like these that include the parameter "height" are not appropriate for studies examining competition (Tappeiner et al. 1992). Seedlings experiencing competition may grow in height (Putz 1992), but at the expense of diameter (and thus ultimate success). The associated increase in height/diameter ratios can be used as a predictor of unsuccessful establishment (Hughes et al. 1990; Tappeiner et al. 1992). Tappeiner et al. (1992) suggest the use instead of diameter growth to quantify growth. In the current study, seedling canopy volume was used in most cases because of its correlation with individual dry weight and its use by other authors (Howard & Newton 1984; Lanini & Radosevich

1986; Shainsky & Radosevich 1986). A few analyses were done with proportional change in stem diameter and they did not indicate more negative (competitive) interactions, supporting the conclusions of this paper.

Height/diameter (H/D) ratio is a possible indicator of competition by neighbors. Hughes et al. (1990) found that 83-88% of the variability in H/D ratio of Douglas-fir seedlings was explained by measures of shrub presence. The authors felt that H/D values greater than 70 indicated likely eventual death. In the current study, 1-30% of the variability in H/D was explained by shrub importance values; only King Gulch West (at 30%) had a value greater than the 8% of the most shrubby site, Elk Creek. These data support the general conclusion that shrub competition is not a significant factor at this time.

It was not the intention of the current study to describe the mechanisms of shrub/seedling interaction. However, the presence of positive associations leads immediately to such questions. Amelioration of the microenvironment, as found around nurse plants in arid locations (e.g. Franco & Nobel 1989; Nobel 1989) is one possible explanation. Also possible is an increase in resources around shrubs (Halvorson et al. 1995). Another possible mechanism involves hydraulic lift (Richards & Caldwell 1987). In this process, plant individuals draw up water from deep soil layers at night and release a portion of it from roots near the soil surface (Dawson 1993; Wan et al. 1993). Its value to the plant is the availability of more water during the day when transpiration water loss is greatest. It has been found that neighbors that root at more shallow depths can use the released water (Dawson 1993).

For this mechanism to explain the beneficial associations found in the current study, the shrub species involved must root at deeper levels than Douglas-fir seedlings of this age. From a literature search (e.g. Wooley 1936; Cannon 1960; Bradley 1984; Stone & Kalisz 1991), discussions with individuals who work with root systems (e.g. T. Foxx, Los Alamos Nat. Laboratory), and field observations made on shrub rooting patterns, some shrub species involved (Ceanothus velutinus, Prunus virginiana, Salix spp., and Ribes spp.) have rooting depths that could permit this mechanism. Others

(Spiraea betulifolia, Physocarpus malvaceus) probably do not. Those species listed above with deeper roots are found frequently (in Tables 5-8) associated with better Douglas-fir growth, while the opposite is true with the more shallowly rooted species listed above. Kris Ablin-Stone (Interdisciplinary Masters student at BSU) has begun a study funded by the Forest Service to determine if hydraulic lift is the cause of the positive associations found here. She will use stable isotope ratios to determine the deep versus shallow origin of water around the lateral surface roots of some deep rooted shrub species. Gratkowski (1961) noted that shrubs appear sometimes to aid forest regeneration and wondered if it has to do with rooting habit; perhaps hydraulic lift is part of the answer.

Proportional change in seedling volume and relative growth rate assume linear and exponential seedling growth, respectively. Since only one site was clearly growing exponentially (Elk Creek), analyses were done with both variables, and all results are presented here. Presumably, all sites will attain exponential growth at some point.

Some authors include seedling initial height in their analyses of factors affecting growth (Elliott & White 1987; Knowe 1995). Though this variable may be influential, it is not relevant to the questions being addressed by this study, and so was not included.

Neighborhood variables found to be significantly associated with seedling growth over the full period of this study were fairly consistent between analyses. However, in the analyses involving only one year of seedling growth, there was great difference in which neighborhood variables were significant. Similarly, the relationships (both positive and negative) between co-occurring annual species were found to differ between years (McConnaughay & Bazzaz 1990). In the current study, it is likely that climatic factors varied between years, affecting both dependent and independent factors; aboveground growth in individual years may thus not reflect long-term growth.

A criticism of this study could be that only seven years of data are available, and that the form of seedling/shrub interactions might change in the next few years. Gratkowski & Lauterbach (1974) and

Youngberg et al. (1979) both note the early benefits of Ceanothus velutinus, but that it subsequently acts as a competitor. Jones (1995), working in south-central Idaho, found a positive association between C. velutinus cover and naturally regenerated seedlings, but noted the likelihood of future competition. The question arises whether in the current study a time will come that negative competitive effects become dominant. Most shrub species appear to have reached their maximum height, with the exception of Salix. In addition, most began the study with established root systems, and thus held the initial advantage underground. The seedling root systems have since become established. It is hard to imagine that in the future shrubs will gain a competitive advantage over seedlings. It is more likely that as seedlings get taller and extend their root systems that they will become more dominant over the shrubs.

The higher, early mortality reported here (Fig. 2) is consistent with the results of others (Tappeiner & Helms 1971; Helgerson et al. 1989; Hobbs et al. 1989; Waters et al. 1991). My survival analyses, based on survival to year 4, included most deaths.

Grass/sedge cover was negatively associated with seedling growth in some locations and neutral in others (Tables 5-8). This is consistent with the relatively shallow rooting of both young Douglas-fir seedlings and grasses/sedges and supports the removal of grasses and sedges, a prescribed planting procedure (Tixier 1982). The odds of seedling survival were slightly increased by grass/sedge cover (Table 3). This could have been caused by soil surface shading, except that nearby grasses and sedges had been scalped according to Forest Service specifications. More precise data on the regrowth of neighboring grass would be need to evaluate these results.

One might hypothesize that the positive associations found in some cases between shrubs and seedlings would be stronger in the drier, grass/sedge dominated habitat types (Psme/cage, Psme/caru) than in the moister, shrub dominated ones (Psme/spbe, Psme/phma, Psme/syor, Psme/acgl). However, my data does not support this hypothesis. With regards to seedling survival, the pattern of mortality was not different between the two groups (Fig. 2). Similarly, in both groups, most shrub species were not

significantly associated with seedling growth, and the majority of significant associations were positive (Tables 5-8).

The design of this research does not allow the inference of causation, only association (Wagner & Radosevich 1991a). The analyses show positive associations between some shrub species and the growth of Douglas-fir seedlings. This does not indicate that the shrubs have caused better growth of the seedlings, though such causation is a logical possibility, and possible mechanisms for it are discussed in this paper. It may be that the shrubs are simply located in microenvironments that are more conducive to seedling growth (Geier-Hayes 1994). The management recommendations of this project still hold -- placing Douglas-fir seedlings near certain shrub species appears to provide for better growth.

The results reported here are from Douglas-fir forests located in south-central Idaho. Because of the variability seen within this study and others (Conard & Sparks 1993), any generalizations to other locations or forest types must be made with care.

Recommendations

The results presented here suggest that planting seedlings near certain shrub species can be beneficial to seedling survival and growth. Two species, Spiraea betulifolia and Physocarpus malvaceous, were associated with reduced growth, and are not included in this recommendation. Shrub species more often associated with increased seedling growth included Salix spp, Ceanothus velutinous, and Ribes spp. An exact planting distance cannot be recommended, only that it be within the 1.5 m neighborhood used in this study. It has been noticed that seedlings directly under large Salix individuals are tall and thin and not as healthy looking, but those just outside the canopy are thriving. A slightly larger planting distance is probably advisable with this species. Increased odds of seedling survival were associated with shrubs having the potential to shade; this suggests that seedlings should be planted in a

northerly direction relative to shrubs.

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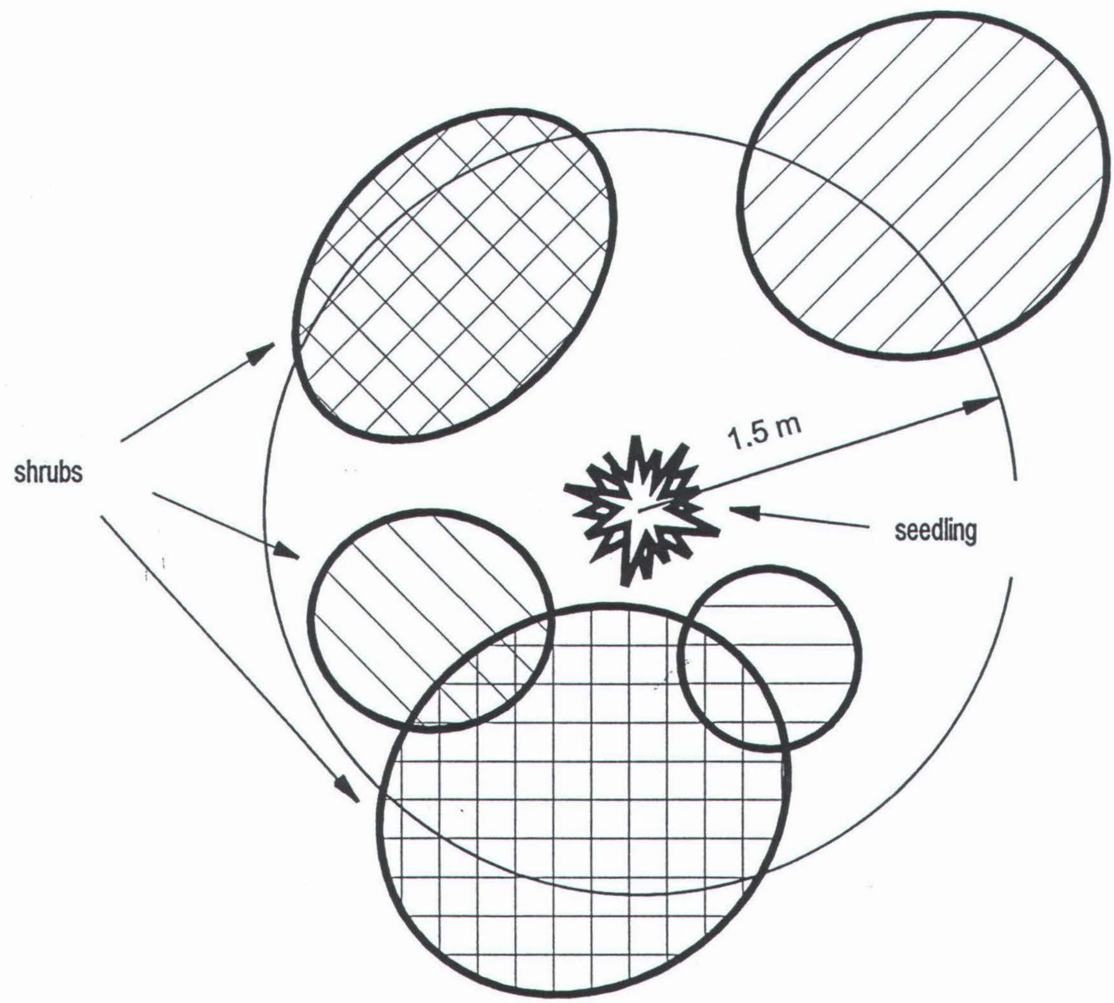

Fig. 1 Diagram of neighborhood around seedling within which variables are measured.

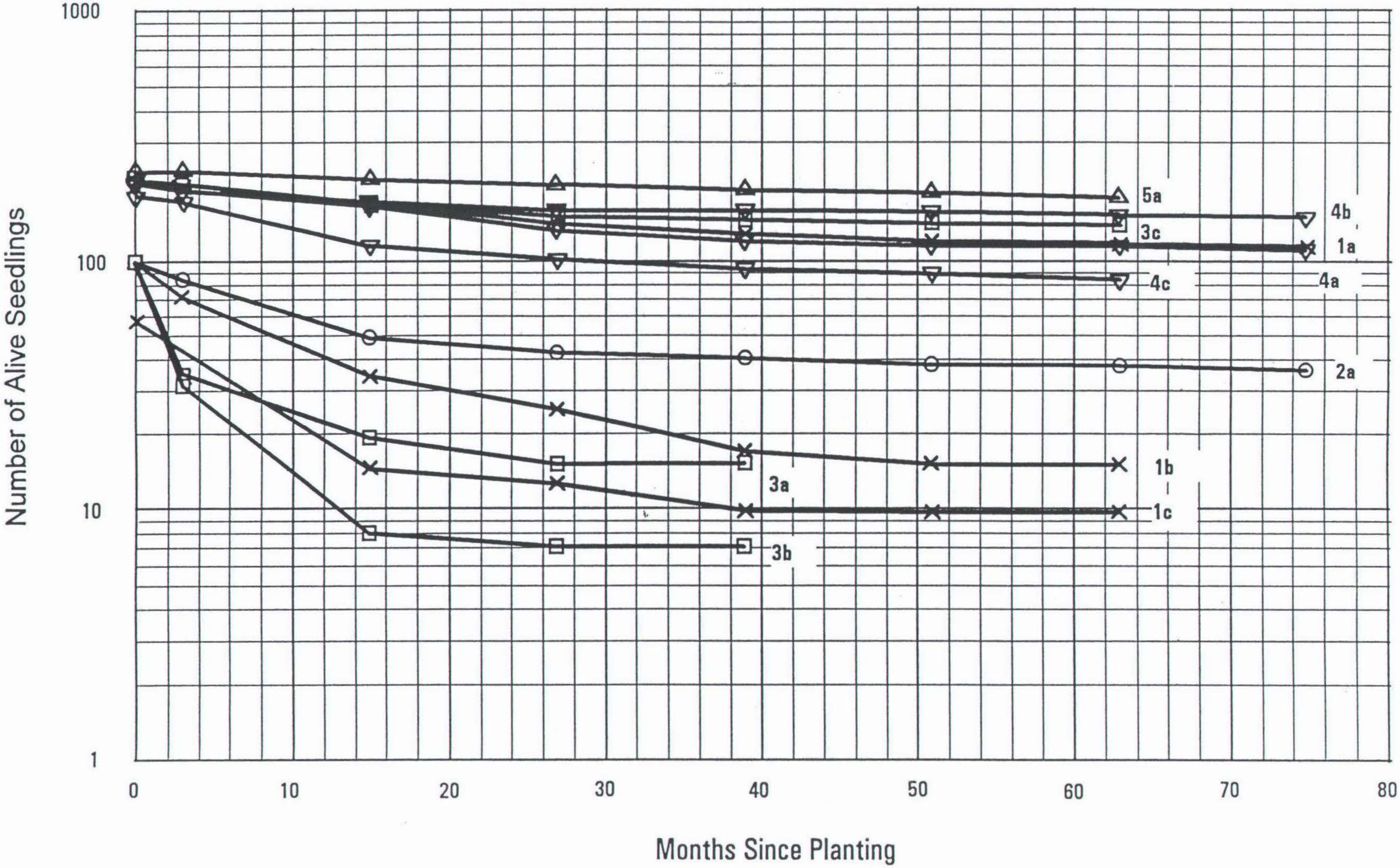

Fig. 2 Seedling survivorship since planting. Symbols: × cage study sites; ○ caru study site; □ spbe study sites; ▽ phma study sites; △ syor and acgl study site.

Table 1. Study sites. Site numbers 1-5 refer to habitat types including cage, caru, spbe, phma, and syor/acgl respectively. See Study Sites section for habitat type abbreviations. * - recent burn.

Site Name and Code	Habitat Type	Elevation	Predominant Aspect	Date Planted	Number of Seedlings Planted
Warm Springs (1a)	Psme/cage	4800'	E	4/22/89	199
Alder Creek Summit (4a)	Psme/phma	5000'	SE	4/26-27/89	200
Elk Creek * (4b)	Psme/phma	5600'	NW	5/10-11/89	200
Nixon Rock (2a)	Psme/caru	6000'	W	5/12-13/89	101
(1a, 1b)	Psme/cage	6200'	S	5/12-13/89	201
Lone Pine (3a, 3b)	Psme/spbe	5800'	W	5/29-30/89	198
King Gulch West * (3c)	Psme/spbe	5500'	NE	4/13-14/90	213
King Gulch East * (5a)	Psme/syor and Psme/acgl	6200'	SE	4/20-21/90	233
Thompson Gulch (4c)	Psme/phma	5600'	N	5/8-9/90	181

Table 2. Shrub species included in this research.

Species	Forest Service Acronyms and Other Names Used in This Paper
Spiraea betulifolia	spbe
Physocarpus malvaceus	phma
Ceanothus velutinus	ceve
Amalanchier alnifolia	amal
Salix spp.	Salix
Prunus emarginata	prem
Prunus virginiana	prvi
Symphoricarpos albus	syal
Symphoricarpos oreophilus	syor
Ribes spp.	Ribes
Purshia tridentata	putr
Lonicera utahensis	lout
Ceanothus sanguineus	cesa
Sorbus scopulina	sosc
Acer glabrum	acgl
Sambucus cerulea	sace

		Shrub importance values defined as:			
		volume/distance^2	height/distance^2	height/distance^2 (only shrubs at angles ± 100° from south included)	height/distance^2 (close and tall)
		(SIV A)	(SIV B)	(SIV C)	(SIV D)
All sites, survival to year 4 (excluding shade and herbaceous cover variables)*	SIV's	1.04	1.30	9.82	3.63
	Slope	0.95	0.94	0.94	0.94
	Grass cover	1.03	1.03	1.03	1.03
	Bush cover	1.08	1.08	1.04	1.08
Sites with all variables measured, survival to year 4 **	SIV's	--	1.21	4.51	2.21
	Slope	1.06	1.05	1.04	1.05
	Grass cover	1.07	1.07	1.07	1.07
	Bush cover	1.10	1.09	1.05	1.08
	Herbaceous cover	1.06	1.06	1.05	1.06

Table 3. Results of logistic regression on seedling survival. SIV's were defined in four ways (as shown above), and represent shrub species combined in a neighborhood. For a unit change in an individual variable, the odds of survival change by the values given above. If value = 1, there is no change in odds of survival. $P < 0.05$ for a variable to be entered into model.

* Including seedlings that lived 3 months or more.

** Including seedlings that lived 12 months or more.

Neighborhood variables	Shrub importance values defined as:		
Shrub Species:	volume/ distance^2 (SIV A)	height/ distance^2 (SIV B)	height/ distance^2 (only shrubs at angles $\pm 100^{\circ}$ from south included) (SIV C)
spbe		+	+
phma			+
ceve	+	+	+
amal	–		
Salix			
prem			
prvi	+		+
syal	–	–	
syor			+
Ribes			+
Others:			
slope	–	–	–
grass cover	+	+	+
bush cover	+	+	+

Table 4. Results of logistic regression on seedling survival, to year 4. SIV's were defined in three ways (as shown above), and represent individual shrub species.

+ Significant positive effect ($P \leq 0.05$);

– Significant negative effect ($P \leq 0.05$).

Table 5a. Results of stepwise linear regressions using 1993 data. Dependent variable is proportional change in seedling volume since planting. Independent variables listed are those with $P < 0.05$, that are within an analysis with overall r^2 as follows:

$r^2 > 0.20$: ↑↑↑ (positive) ; ↓↓↓ (negative)
$0.15 < r^2 < 0.20$: ↑↑ (positive) ; ↓↓ (negative)
$0.10 < r^2 < 0.15$: ↑ (positive ; ↓ (negative)

Site	Positive	Negative
1a	ceve ↑↑↑ Salix ↑↑↑ bush cover ↑↑↑ slope ↑↑↑	grass cover ↓↓↓
4a	_____	_____
4b	Ribes ↑↑↑	spbe ↓↓↓ grass cover ↓↓↓ pm shade ↓↓↓
1b, 1c	syor ↑↑↑ Ribes ↑↑↑ sace ↑↑↑	_____
2a	amal ↑↑↑	_____
3c	_____	grass cover ↓
4c	Ribes ↑↑↑ pmshade ↑↑↑	bush cover ↓↓↓ slope ↓↓↓
5a	acgl ↑	_____

Table 5b. As in Table 5a, but using 1994 data. * = no data

Site	Positive	Negative
1a	ceve ↑↑↑ Salix ↑↑↑ bush cover ↑↑↑ slope ↑↑↑	grass cover ↓↓↓
4a	_____	_____
4b	Salix ↑↑	spbe ↓↓ grass cover ↓↓ pmshade ↓↓
2a	*	*
3c	*	*
4c	Ribes ↑↑ pmshade ↑↑	bush cover ↓↓
5a	_____	_____

Table 5c. As in Table 5a, but using 1995 data

Site	Positive	Negative
1a	ceve ↑↑↑ slope ↑↑↑	grass cover ↓↓↓
4a	_____	_____
4b	ceve ↑↑↑ <u>Salix</u> ↑↑↑ prem ↑↑↑ bush cover ↑↑↑ herbaceous cover ↑↑↑	phma ↓↓ middayshade ↓↓↓
2a	amal ↑↑↑	_____
3c	<u>Salix</u> ↑↑ prvi ↑↑	grass cover ↓↓
4c	_____	_____
5a	ceve ↑ acgl ↑ bush cover ↑	_____

Table 6. Results of stepwise linear regressions using 1995 data. Dependent variable is seedling relative growth rate (RGR) since planting. Otherwise, see Table 5a caption.

Site	Positive	Negative
1a	slope ↑↑↑	grass cover ↓↓↓
4a	_____	_____
4b	ceve ↑↑↑ Salix ↑↑↑ prem ↑↑↑ bush cover ↑↑↑ herbaceous cover ↑↑↑	grass cover ↓↓↓ middayshade ↓↓↓
2a	amal ↑↑	herbaceous cover ↓↓↓
3c	bush cover ↑	_____
4c	_____	_____
5a	ceve ↑ acgl ↑ bush cover ↑	amal ↓

Table 7. Results of stepwise linear regressions using 1993, 1994 and 1995 data. Dependent variable is proportional change in seedling volume over a one-year period. Otherwise, see Table 5a caption. * = no data; ** = analysis not done.

	1995 data		1994 data		1993 data	
Site	Positive	Negative	Positive	Negative	Positive	Negative
1a	Herbaceous cover ↑↑↑ slope ↑↑↑	Ribes ↓↓↓	_____	_____	_____	_____
4a	amal ↑↑↑ syal ↑↑↑ syor ↑↑↑	phma ↓↓↓	_____	_____	syor ↑↑ Ribes ↑↑	_____
4b	_____	_____	_____	_____	_____	_____
2a	Ribes ↑↑↑	_____	*	*	amal ↑↑↑	_____
3c	prem ↑	grass cover ↓	*	*	**	**
4c	ceve ↑↑ syor ↑↑↑ herbaceous cover ↑↑↑	_____	ceve ↑↑↑ amal ↑↑↑ slope ↑↑↑	grass cover ↓↓↓	**	**
5a	_____	_____	ceve ↑↑↑ Salix ↑	pmshade ↓↓↓	**	**

Table 8. Results of stepwise regression using 1995 data. Dependent variable is proportional change in stem diameter since planting. Otherwise, see Table 5a caption.

Site	Positive	Negative
1a	ceve ↑↑ herbaceous cover ↑↑	_____
4a	_____	_____
4b	prem ↑↑ bush cover ↑↑↑	phma ↓↓↓ middayshade ↓↓↓
2a	amal ↑↑	_____
3c	_____	_____
4c	<u>Ribes</u> ↑↑ herbaceous cover ↑↑	_____
5a	ceve ↑ <u>Salix</u> ↑ bush cover ↑	_____